



CALIFORNIA HYDROGEN HIGHWAY NETWORK



HYDROGEN AND HYDROGEN TECHNOLOGIES FREQUENTLY ASKED QUESTIONS

Why hydrogen?

Hydrogen has many important advantages over other fuels. Hydrogen can be made from renewable sources, it is clean to use, and it is the fuel of choice for energy-efficient fuel cells. Hydrogen will play a critical role in a new, decentralized energy infrastructure that can provide power to vehicles, homes, and industries.

Hydrogen has the ability to address several high-priority areas for California:

- **Energy security and diversity:** Hydrogen can be produced from a variety of domestic sources, including renewable sources. This enables diversification of our energy supply, especially in the transportation sector, which is currently almost entirely dependent on petroleum fuels.
- **Environmental protection:** Hydrogen fuel can be used in vehicles powered by either internal combustion engines or fuel cells, resulting in near-zero or zero tailpipe emissions. When hydrogen is produced from renewable resources and used to power fuel cell vehicles, the entire chain of processes (fuel production through end use in a vehicle) results in extremely low environmental impacts.
- **Economic development:** California has long been at the forefront of emerging high-technology industries. Early support for these industries can translate into job-creation benefits as technologies flourish in the marketplace. If California continues to lead in creating demand for hydrogen fuel stations and products, companies with related technologies are more likely to choose our state to locate new technology centers and manufacturing facilities.

Where does hydrogen come from?

Hydrogen is the most abundant element in the universe, and can be found in water, fossil fuels and other sources. It bonds with other elements to form molecules such as water, methane (natural gas) and methanol. Hydrogen is produced by unlocking the chemical bonds in these molecules. The water molecule, for example (H₂O), consists of two hydrogen atoms bonded to an oxygen atom. One way to produce hydrogen is to use energy to break water apart through a process called electrolysis. In this process, electricity is passed through water in the presence of a catalyst to separate the hydrogen from the oxygen. Another approach is to liberate the hydrogen by "reforming" fuels such as gasoline or natural gas.



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Is hydrogen safe?

Hydrogen is no more and no less safe than gasoline and other motor vehicle fuels. Hydrogen, which exists as a gas under normal atmospheric conditions, is odorless, colorless, tasteless, and non-toxic. It can also be safely transported.

Like any fuel, hydrogen is flammable. Hydrogen's flammability properties are different than those of gasoline and, therefore, it has different handling requirements. Hydrogen, for instance, can ignite with less energy than gasoline, but requires a greater concentration of hydrogen and oxygen to burn. Hydrogen is extremely light and buoyant, and it dissipates into the open air very quickly, making any flammable concentration of hydrogen unlikely.

Hydrogen stations and vehicles utilize many redundant safety systems to ensure the fuel system shuts down and concentrations of hydrogen are too low to be unsafe. Large amounts of hydrogen have been produced for commercial and manufacturing uses for many decades, with an exemplary safety record.

What about the Hindenburg?

Unfortunately, the Hindenburg tragedy contributed to a negative reputation for hydrogen. The airship was not destroyed because it was filled with hydrogen. The material used as the skin of the airship was highly flammable and caught fire from static electricity. When the skin burned, the lighter-than-air hydrogen escaped and, as would be expected with any flammable substance, it also burned. The largest contributor to the fire was from the skin of the airship, not hydrogen.

How much will hydrogen fuel cost?

The answer depends on how the hydrogen is produced and delivered. Currently, the cost of hydrogen is greater than the cost of gasoline. Development work is ongoing to bring the cost of hydrogen down to be competitive with the cost of gasoline by the time fuel cell vehicles are commercially available.

What is a fuel cell?

A fuel cell is an electrochemical device that produces electricity efficiently, silently and without combustion. Hydrogen is combined with oxygen (from air) to produce electrical energy.

How do hydrogen fuel and oxygen produce electrical energy?

A Proton Exchange Membrane fuel cell is made of two plates sandwiched together with a plastic membrane coated with a catalyst. Hydrogen and oxygen are fed through channels in the plates on either side of the membrane. The hydrogen and oxygen atoms are attracted to each other; however, only the proton part of the hydrogen atom can pass through the membrane to reach the



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oxygen. The electron has to take the long way around the membrane to reach the oxygen atom - creating energy in the process. The hydrogen electron is eventually united with the proton and oxygen atom to create water (H₂O).

What are the benefits of fuel cell technology?

The most impressive fuel cell benefits are their high efficiency and zero emissions. In addition, fuel cell technology can help reduce dependence on petroleum because fuel cells use hydrogen, and hydrogen can be produced from many sources, including renewable sources. When using hydrogen, fuel cells don't emit any pollution or greenhouse gases. The only by-product is water vapor.

The electric drive train of fuel cell vehicles provides other benefits, too. An electric motor gives these vehicles very high torque for quick starts and a quiet ride. In addition, fuel cells create plenty of on-board power for devices such as GPS and DVD players. Fuel cells are powerful, have the potential to be easy to maintain, and can contribute to reducing noise pollution, a significant issue in urban areas.

What is the difference between a fuel cell and a battery?

Fuel cells and batteries are similar as they both deliver electrical power from a chemical reaction. However, in a battery, the chemical reactants are stored within the battery and are used up during the reaction. Then, the battery must be recharged or thrown away. In a fuel cell, the reactants (H₂ and O₂) are stored externally to the fuel cell, so it will keep producing electricity as long as reactants are delivered to the fuel cell. Therefore, a fuel cell vehicle is refueled instead of recharged.

Who will make hydrogen?

Oil companies are evolving and changing, as energy needs are changing. Some oil companies see diversification of their portfolios as a means to ensuring future profitability. It is these "energy companies" that are among the forerunners in development and deployment of hydrogen production and fueling facilities.

Who will make hydrogen vehicles?

All of the world's major auto manufacturers have well-established hydrogen vehicle research and development projects. Many, including Ford, General Motors, Honda, Toyota, DaimlerChrysler, Nissan, Hyundai, and Volkswagen have already begun deploying—or will soon deploy hydrogen fuel cell vehicles in everyday, real-world applications in California. In addition, fuel cell buses are already in revenue service in transit agencies around the state.



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What are the major activities that must be accomplished in order to commercialize fuel cell vehicles?

- Prove the reliability and durability of the fuel cell
- Increase range by improving how hydrogen is stored on board the vehicle
- Reduce the cost of building fuel cell vehicles to be competitive with today's cars
- Invest in infrastructure to support wide-scale vehicle introduction
- Secure public acceptance to create demand for this technology
- Ensure proper safety mechanisms, codes and standards, and practices are in place to safely handle hydrogen fuels and vehicles

When will hydrogen vehicles to be made available to the general public?

The commercialization of hydrogen vehicles will take time. Each automaker has their own market plan. The transition to hydrogen as a vehicle fuel requires careful steps. It is the automakers' belief that hydrogen vehicles, at launch, must be as good as or better than today's internal combustion engine vehicles for successful market adoption. Likewise, the fuel infrastructure choice must develop to support commercial sales. From setting proper codes and standards for safe operation and maintenance of the vehicles, stations and fuel, to creating a new fueling infrastructure and educating consumers...it takes time.

What about other vehicle technologies that are practical, energy efficient, and/or achievable in the near-term?

Complimentary technologies are essential to the development of a hydrogen economy and California should continue to evaluate and support investments made in other alternative fuels and technologies when they offer clear and compelling societal benefits. These technologies are necessary to achieve immediate petroleum and emissions reductions. Examples of such fuels and technologies include, but are not limited to, battery electric propulsion systems, and natural gas systems.

These technologies alone, however, do not have the broad spectrum of attributes that hydrogen has and cannot achieve California's long-term vision. Many potential benefits and factors have been taken into account for success. These include stakeholder support, the stated commercialization plans of vehicle manufacturers, existing partnerships that can be leveraged, synergy with bridging technologies for hydrogen, and potential broad acceptance by the public.

Will hydrogen cause more pollution?

Hydrogen vehicles, themselves, are near-zero or zero emission vehicles. Depending on how the hydrogen fuel is produced, there can be some greenhouse gas emissions and that is why it is important to emphasize producing



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hydrogen from clean, renewable sources of energy such as solar or wind and natural gas in California. An examination the total emissions from the production and use of hydrogen shows that fuel cell vehicles are the cleanest.

What about the fuel cycle energy efficiency of hydrogen vehicles compared to other vehicles?

Cleaner-burning fuels and electric/gasoline hybrids are here today and can provide some short-term solutions to energy efficiency. However, California's goals go beyond just that one attribute. Hydrogen has a combination of compelling benefits that provide the greatest potential to successfully meet the broader needs of the state, including reducing our dependence on petroleum.

Isn't the best way to displace petroleum in the transportation sector to use more hybrid-electric vehicles?

A broader long-term strategy using alternative fuels is needed in order for California to meet its petroleum reduction and environmental goals. Although improvements to gasoline vehicles through hybridization are a near-term component of an overall strategy, California cannot achieve its goals solely through such efforts. This is because the number of vehicle miles traveled by California's motorists is growing at a rate which will overwhelm improvements that hybrids can make.

Doesn't using natural gas prolong California's dependence on fossil fuel?

The use of natural gas for hydrogen is a near term solution. Long term strategies for the production of hydrogen focus on renewable sources.